Containers

Thomas D. Landis, Tara Luna, and R. Kasten Dumroese

7

A nursery container could be anything that holds growing media, drains, allows for healthy root development, does not disintegrate before outplanting, and allows for an intact, healthy root system to be removed with a minimum of disturbance to the plant. Understanding how container properties affect plant health and growth, as well as nursery operations, will help growers choose the best containers for their needs. Container type and dimensions affect root development, amount of water and mineral nutrients available for plant growth, nursery layout, bench size, production scheduling, and plant transportation method. After a container is selected, it can be expensive and time consuming to change to another type.

Most nurseries grow a wide variety of species and therefore several different containers are required (figure 7.1A). Container choice for a particular plant species depends on root system morphology, target plant criteria (see Chapter 3, Defining the Target Plant), and economics. In general, the following points hold true regarding container type:

- Plants that develop shallow, fibrous root systems, as most forbs do, grow better in shorter containers (figure 7.1B).
- Plants with long taproots, such as many kinds of trees, grow better in taller containers (figure 7.1C).
- Plants with multiple, thick, fleshy roots, and species with thick, fleshy rhizomes grow better in wide containers (figure 7.1D).

Facing Page: *Nurseries growing a wide variety of species use many different container types. Photo of Po'o Wai U Nursery on the Big Island of Hawai'i by Diane L. Haase.*

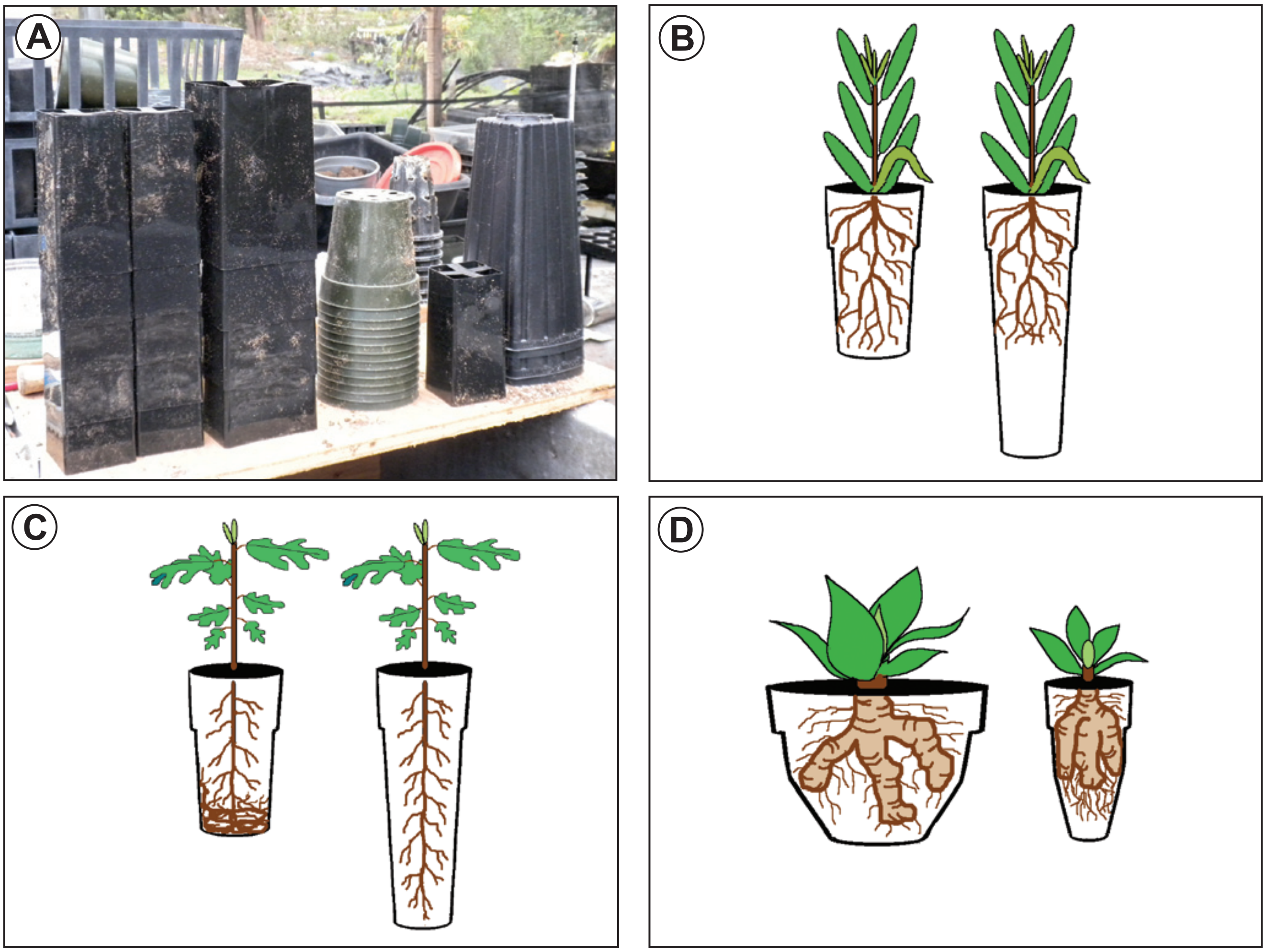

Figure 7.1*—Nurseries use a variety of containers to produce different species and stocktypes (A). Some plants, including most forbs, grow best in shorter containers (B) whereas taprooted species do better in taller ones (C) and fleshy-rooted plants should be grown in short wide containers (D). Photo A by Diane L. Haase, and illustrations B, C, and D adapted from Dumroese and others (2008).*

In the ornamental trade, large individual containers are called "pots" or "cans," but they are simply called "containers" in native plant nurseries. An inexpensive alternative to the plastic pot is the "bag" or polybag, which has the same general purpose and function. Plants grown in small-volume containers are often referred to as "plugs." Plug seedlings are usually grown in individual containers called "cells" or "cavities" that are aggregated into "blocks," "trays," or "racks." Often, many plants will be germinated in a tray, transferred to a small pot, and later transplanted to a larger container. Making the right container choices at the right time is an important task for a nursery manager. This chapter describes some of the key biological and operational considerations necessary for choosing appropriate container types.

Container Characteristics Affecting Plant Development

Volume

The volume of a container dictates how large a plant can be grown in it. Optimum container size is related to the species, target plant size, growing density, length of the growing season, and growing medium used. For example, to grow large woody plants for an outplanting site with vegetative competition, a nursery would choose large-volume containers with low growing densities. This method creates taller plants, with larger stem diameters, which have been shown to survive and grow better under these conditions.

In all nurseries, container size is an economic decision because production costs are a function of how many plants can be grown in a given space in a given time. Larger containers occupy more growing space and take longer to produce a firm root plug. Therefore, plants in larger containers are more expensive to produce, store, ship, and outplant. The benefits, however, may outweigh the costs if the outplanting objectives are more successfully satisfied.

Height

Container height is important because it determines the depth of the root plug, which may be a consideration on dry outplanting sites. Many clients want their plants to have a deep root system that can stay in contact with soil moisture throughout the growing season. Height is also important because it determines the proportion of freely draining growing medium within the container. When water is applied to a container filled with growing medium, gravity percolates it downward until it reaches the bottom and runs out of the drain holes in the bottom of the container. There, it stops because of its attraction for the growing medium, creating a saturated zone that always exists at the bottom of any container. Container height and the type of growing medium control the depth of this saturated layer. With the same growing medium, the depth of the saturation zone is always proportionally greater in shorter containers (figure 7.2). For example, a 4-in (10-cm) tall container will have the same depth of saturation as a 10-in (25-cm) tall container, but the 4-in-tall container will have a smaller percentage of freely drained medium.

Diameter

Container diameter is important in relation to the type of species being grown. Broad-leaved trees, shrubs, and herbaceous plants need a larger container diameter so that irrigation water applied from above can penetrate the dense foliage and reach the medium. Diameter also affects growing density in the nursery.

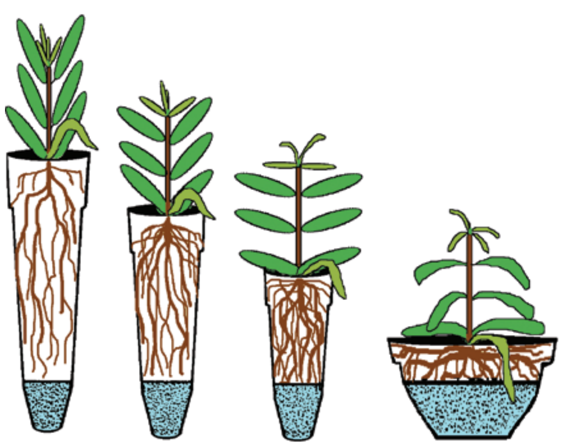

Figure 7.2*—A saturated layer of growing medium always exists in the bottom of containers. With the same growing medium, the proportion of saturated media is greater for shorter containers. Adapted from Landis and others (1989).*

Shape

Containers are available in a variety of shapes and most are tapered from top to bottom. Most containers are round but some are square and maximize the growing space used in the greenhouse. Container shape is important as it relates to the type of outplanting tools used and the type of root system of the species grown.

Plant Density

The distance between plants is another important factor to consider. Spacing affects the amount of light, water, and nutrients that are available to individual plants (figure 7.3A). In general, plants grown at closer spacing grow taller and have smaller stem diameters than those grown further apart (figure 7.3B). Plant leaf size greatly affects growing density. Broad-leaved species should be grown only at fairly low densities, whereas smaller leaved and needle-leaved species can be grown at higher densities. Container spacing will affect height, stem straightness, stem diameter, and bushiness. Container spacing also affects nursery cultural practices, especially irrigation. Trays holding individual containers provide some flexibility in spacing because, as

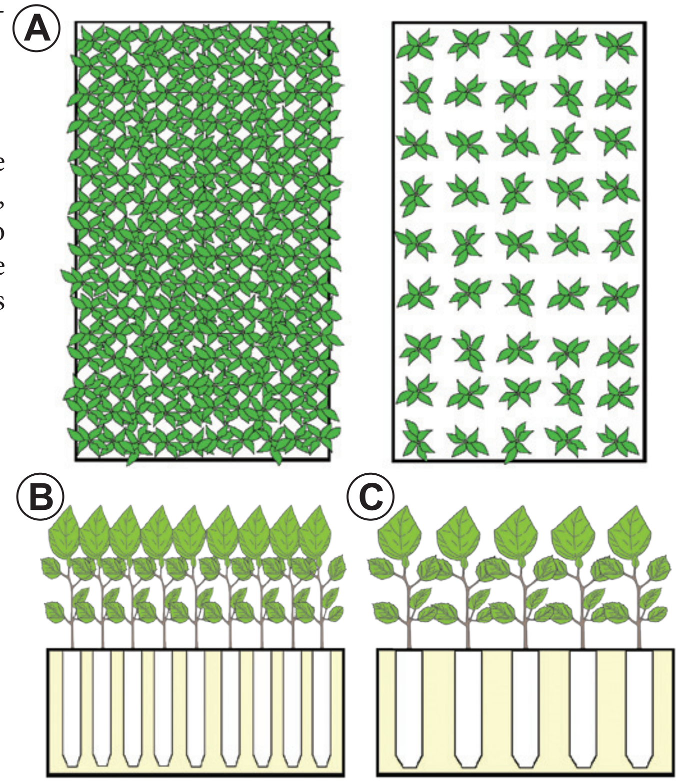

Figure 7.3*—Next to volume, spacing is the most important characteristic in container choice (A). Plants grown too close together become tall and spindly and have less stem diameter (B). Trays with removable containers are popular because they allow flexibility in spacing between plants(C). Adapted from Dumroese and others (2008).*

Table 7.1—*Effects of container density.*

High density	Low density
Plants will be taller and have smaller stem diameters	Plants will be shorter and have larger stem diameters
Difficult to irrigate and fertilize with overhead sprinklers because water and liquid fertilizers need to penetrate dense patches of foliage	Easier to irrigate and fertilize with overhead sprinklers
Greater likelihood of foliar diseases due to poor air circulation between plants	Easier to irrigate and fertilize with overhead sprinklers
Cooler medium temperature	Better air circulation between seedlings; less disease problems
Foliage in lower crown will die because of shading	Plants have fuller crowns because more light reaches lower foliage
Greater number of plants can be grown in an area requiring less space and sometimes lower costs.	Fewer plants can be grown in a given area of the nursery

the plants grow, one-half of the containers can be moved to another tray, thereby allowing greater space between plants (figure 7.3.C). Some of the other effects of plant growing densities are shown in table 7.1.

Drainage Holes

Containers must have a bottom hole or holes large enough to promote good drainage and encourage "air pruning." Roots stop growing when they reach an air layer under the container. Some containers feature a bottom rail to create this air layer (figure 7.4A), whereas flat-bottomed containers must be placed on specially designed benches (figures 7.4B, 7.4C) or on a bed of coarse gravel. The drainage hole must also be small enough to prevent excessive loss of growing medium during the container-filling process. The correct drainage hole size is related to the type of medium you use; different types of containers work better with certain media types. Sandy mixes, for example, are more likely to fall out of large holes while media rich in fibrous organic material tend to hold together.

Root Pruning

Spiraling and other types of root deformation have been one of the biggest challenges for container growers, and nursery customers have concerns about potential problems with root-binding after outplanting (figure 7.5A). Research shows that rootbound seedlings are more likely to perform poorly or even blow over after outplanting. In addition to holes on the bottom of the container for air root pruning, many containers have vertical ribs within the container to force the roots to grow downward.

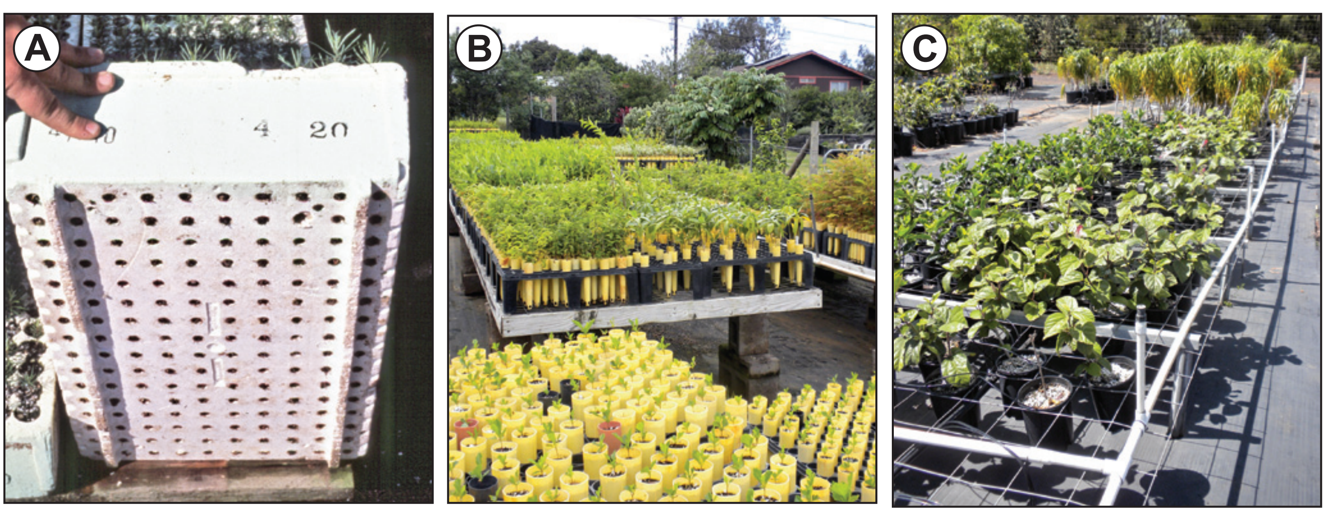

Figure 7.4—*Some block containers are designed to promote air pruning (A). Other containers must be placed on mesh-topped benches (B) or be supported (C) to create an effective air space underneath. Photo A by Thomas D. Landis, and photos B and C by Diane L. Haase.*

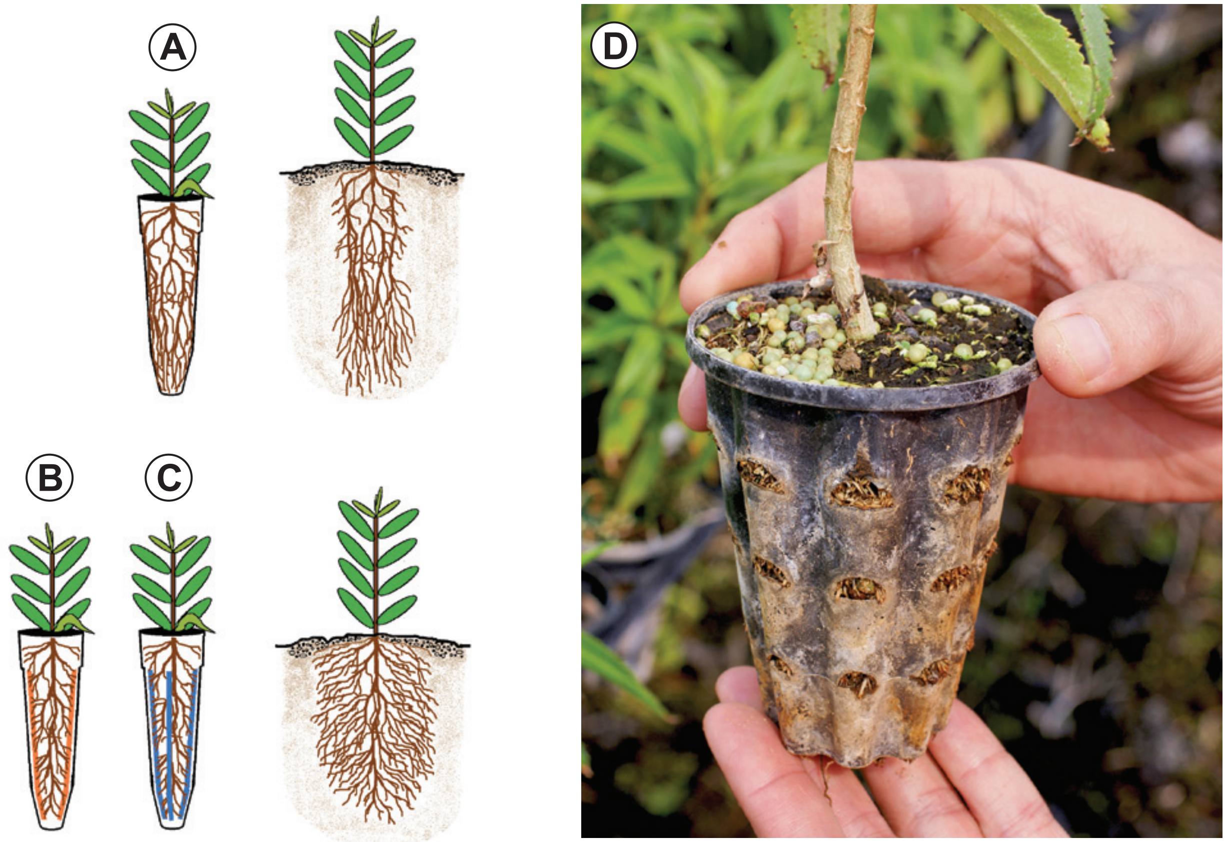

***Figure 7.5**—Plants with aggressive roots often exhibit spiraling and other deformities after outplanting. If rootbound, roots often do not grow out beyond the original plug (A). Containers coated with copper will chemically prune roots (B), and other containers are available with lateral slits to reduce spiraling and encourage air pruning and on the side of the plug (C, D). Illustrations A, B, and C adapted from Dumroese and others (2008), and photo D by Thomas D. Landis.*

Inappropriate Containers and Growing Media

In an effort to save the cost of purchasing trees from the local nursery, an engineering firm decided to produce its own large mahogany trees for roadside planting projects. Because 55-gal drums were available in large quantities, they were cut in half and filled with local soil. Young mahogany seedlings were planted in the drums and watered regularly for nearly 3 years. The trees grew to be 15 to 20 ft (5 to 6.5 m) tall and were deemed to be the perfect size for the project (figure 7.6). The soil used was rich in clay and the containers did not have sufficient drainage holes, however, causing the root systems to be severely stunted. Even worse, the drums and clay made the trees too heavy to be transported easily. In the struggle to transport them and to remove them from the containers, the trees were damaged. In the end, transport costs tripled and one-third of the trees had to be replaced. Poor planning and improper containers turned this money-saving idea into a very costly project.

***Figure 7.6**—Inappropriate containers and growing media can lead to serious problems, as with these mahogany trees in soil-filled 55-gallon drums. Photo by Brian F. Daley.*

Chemical pruning involves coating the interior container walls with chemicals that inhibit root growth (figure 7.5B), such as cupric carbonate or copper oxychloride. Copper-coated containers are available commercially (such as the Copperblock™). Some nurseries apply the chemical by spraying or dipping the containers. It can even be applied to polybags to greatly improve plant quality and outplanting performance, as described under the section on polybags. Fabrics treated with Spin-Out™ or similar copper coating can be placed as a groundcover under containers to prevent rooting into the ground. Copper toxicity has not been shown to be a problem for most native species, and the leaching of copper into the environment has been shown to be minimal.

Several companies have developed containers that feature air slits on their sides to control root deformation by air pruning (figures 7.5C, 7.5D). In the same manner as plant roots air prune when they reach the bottom drainage hole, they also stop growing and form suberized tips when they reach the lateral slits in sideslit containers. Using these containers (such as the RootMaker®) requires managing for (1) roots that sometimes bridge between containers and (2) seedlings in sideslit containers that dry out much faster than those in containers with solid walls.

Root Temperature

Color and insulating properties of the container affect medium temperature, which directly affects root growth. Black containers can quickly reach lethal temperatures in full sun whereas white ones are more reflective and less likely to have heat buildup. In hot, sunny climates, a grower should use containers in white or other light-reflecting colors to protect against root injury (figure 7.7). Another option is to use white plastic, Styrofoam™, or other insulating material around the outside perimeter of the containers.

Economic and Operational Factors Affecting Container Choice

Cost and Availability

Associated expenses for various container types, such as shipping and storage costs, must be considered in addition to purchase price. Nursery managers in the tropics often face high shipping costs and long shipping times. Long-term availability must also be considered to ensure that ample supplies of the container can be secured in the foreseeable future. The environmental costs must also be considered and a number of new alternative container types are becoming available, made with recycled or green materials (Nambuthiri and others 2013).

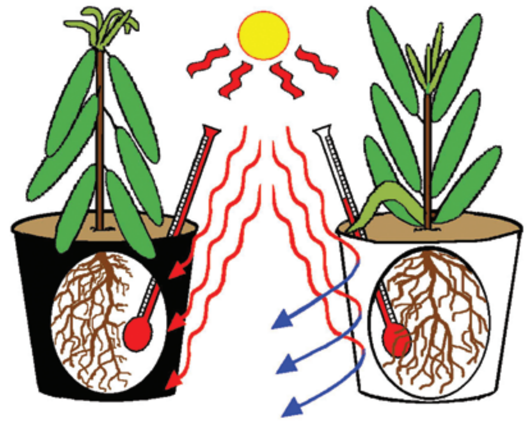

Figure 7.7—*Container color is a consideration, especially when containers are exposed to direct sunlight. Roots in white containers stay cooler than those in black ones. Adapted from Dumroese and others (2008).*

Durability and Reusability

Containers must be durable enough to maintain structural integrity and contain root growth during the nursery period. Containers made out of rolled newspaper have gained popularity amongst gardeners; however, these containers disintegrate too quickly to be suitable for growing plants on a nursery scale. The intense heat and ultraviolet rays in container nurseries can cause even some types of plastics to become brittle and break, although many container plastics now contain ultraviolet (UV) inhibitors. Some containers are designed to be used only once, whereas others can be reused for 10 or more crop rotations. Reusability must be considered in the container cost analysis because the cost of reusable containers can be amortized over their life span after adjusting for the cost of handling, cleaning, and sterilizing of the containers between crops (discussed later in this chapter).

Refundable Deposits for Containers and Trays

Containers are expensive, and most are made of plastic—a nonrenewable, petroleum-based product. Although alternative containers made from renewable resources are being developed (Chappell and Knox 2012, Nambuthiri and others 2013), many of these have not yet been adequately tested in tropical nurseries. Reusing containers is important to save money and resources and to protect the environment from waste. Charging a refundable container deposit (similar to bottle deposits for beverage containers) encourages clients to return containers to the nursery for reuse. Used containers need to be washed and sterilized after they are returned to the nursery.

Ease of Handling

Containers must be moved several times during crop production, so handling can be a major concern from logistic and safety standpoints. Collapsible or stackable containers, such as Zipset™ Plant Bands or Spencer-Lemaire Rootrainers™, have lower shipping and storage costs; they must, however, be assembled before filling and sowing and thus require additional handling. The size and filled weight of a container will affect ease of handling. Containers must be sturdy enough to withstand repeated handling.

Large containers are increasing in popularity, but they become very heavy when saturated with water. Weight must also be considered for shipping and field planting. It is easier for a tree planter to carry and plant hundreds of trees if the seedlings are small. With large containers, the outplanting may go slower, but survival and ability to outcompete other vegetation will likely be greater. If containers will be shipped or trucked to the outplanting site, then the type of shipping and storage system must be considered during container selection. If seedlings are to remain in the container, then some sort of shipping box must be used to protect them. Pros and cons exist with every method, and it is up to you to know the needs of your plants, clients, and site conditions for outplanting to choose the best option, as discussed in Chapter 3, Defining the Target Plant.

Ability to Cull, Consolidate, and Space

One advantage of tray containers with interchangeable cells is that cells can be removed from the tray and replaced. This advantage is particularly useful during thinning, when empty cells can be replaced with cells containing a germinant, and during roguing, when diseased or otherwise undesirable plants can be replaced with cells containing healthy ones. Plants of the same size can be consolidated and grown under separate irrigation or fertilizer programs. This consolidation can save a considerable amount of growing space in the nursery. This practice is particularly valuable with seeds that germinate slowly or unevenly, and so exchangeable cells are very popular in tropical nurseries. Another unique advantage is that cells can be spaced farther apart by leaving empty slots; this practice is ideal for larger leaved plants and also for promoting good air circulation later in the season when foliar diseases can become a problem.

Holdover Stock

Some nurseries will hold onto their stock without transplanting in an effort to reduce costs and save growing space, hoping that the stock will be outplanted next year. This practice, however, can result in the root system becoming too rootbound to grow well after outplanting (figure 7.8), as discussed in Chapter 4, Crop Planning: Propagation Protocols, Schedules, and Records, and Chapter 15, Hardening. If nursery stock must be held over, then the nursery needs to keep a supply of larger containers so the plants can be transplanted to keep the root systems healthy and to maintain good shoot-to-root balance.

Figure 7.8*—Many tropical plants have aggressive roots and cannot be held over from one growing season to the next or they will become dangerously rootbound. Photo by Thomas D. Landis.*

Types of Containers

Many types of containers are available, and each has its advantages and disadvantages. It is a good idea to try new containers for each species on a small scale before buying large quantities. Several containers types are used in container plant nurseries and can vary considerably in size (table 7.2).

One-Time-Use Containers

One of the first major distinctions in container types is whether they will be used once or whether they can be cleaned and used again. Some one-time-use containers, such as Jiffy® products, can be outplanted directly whereas others, such as Zipset™ Plant Bands, are removed and discarded at the time of outplanting. The idea of growing a plant in a container that can be transplanted or outplanted directly into the field is attractive, and many designs have been tried. Most of these early attempts failed because the

> *"Seedlings produced in a nursery in Indonesia using root trainers and a peat-based growing media cost about 20 percent more than seedlings produced in a neighboring nursery using polybags and topsoil. But reduced transport costs to the field and better seedling survival and growth eliminated this difference completely."* (Jaenicke 1999: 27)

Table 7.2—*Volumes and dimensions of containers used in native plant nurseries. Adapted from Stuewe and Sons, Inc. (2013), and other sources.*

Container brand or type	Volume in3 (ml)	Depth in (cm)	Top diameter in (cm)
One-time-use containers			
Jiffy® pellets	0.6 to 21.4 (10 to 350)	1.2 to 5.9 (3 to 15)	0.8 to 2.2 (2.0 to 5.6)
Jiffy® pots	4.4 to 137.7 (72 to 2,257)	1.9 to 5.9 (4.9 to 15.0)	2.0 to 6.5 (5.1 to 16.5)
Zipset™ plant bands	6 to 42 (98 to 688)	4 to 14 (10 to 36)	1.5 to 3 (3.8 to 7.6)
Single free-standing containers			
RootMaker® singles	6.0 to 13.25 (172 to 1,125)	6.0 to 11.3 (15.3 to 28.7)	6.0 to 13.3 (15.3 to 33.8)
Polybags	90 to 930 (1,474 to 15,240)	4 to 8 (10 to 20)	6 to 8 (5 to 20)
Treepots™	101 to 1,848 (1,655 to 30,280)	9.5 to 24.0 (24 to 60)	3.8 to 11.0 (10 to 28)
Round pots	90 to 4,500 (1,474 to 73,740)	6 to 18 (15 to 45)	6 to 14 (15 to 35)
Containers with exchangeable cell held in a tray or rack			
Ray Leach Cone-tainer™ cells	3 to 10 (49 to 164)	4.75 to 8.25 (12 to 21)	1.0 to 1.5 (2.5 to 3.8)
Deepots™	13 to 60 (210 to 983)	3 to 14 (7.6 to 36)	2 to 2.5 (5 to 6.4)
Book or sleeve containers			
Rootrainers™	3.3 to 67 (55 to 1,100)	4.25 to 10.0 (10.8 to 25.4)	1.0 x 1.0 to 3.0 x 2.5 (2.5 x 2.5 to 3.0 x 2.5)
Rectangular blocks composed of cavities or cells			
Styroblock™ and Copperblock™	0.5 to 195.3 (8 to 3,200)	2 to 7 (5.1 to 17.9)	0.6 to 6.2 (1.4 to 15.8)
Ropak® Multi-Pots™	3.5 to 6.0 (57 to 98)	3.5 to 4.75 (9 to 12)	1.25 to 1.5 (3.2 to 3.8)
IPL Rigi-Pots™	0.3 to 21.3 (5 to 350)	1.7 to 5.5 (4.4 to 14.0)	0.55 x 0.55 to 2.3 x 2.3 (1.4 x 1.4 to 5.9 x 5.9)
Hiko™ Trays	0.8 to 32.3 (913 to 530)	1.9 to 7.9 (4.9 to 20.0)	1.0 to 1.3 (2.5 to 3.3)
Miniplug trays			
"Groove Tube" System™	1.4 to 11.7 (23 to 192)	2.50 to 5.25 (6.4 to 13.3)	1.13 to 2.25 (2.9 to 5.7)
RootMaker® propagation trays	1.6 to 6.0 (26 to 172)	2.0 to 4.0 (5.1 to 10.2)	6.0 to 13.3 (15.3 to 33.8)

Figure 7.9—Jiffy® pellets are composed of dry compressed peat surrounded by mesh and expand when watered. Smaller pellets are used to start germinants and can be transplanted into larger Jiffy® containers or other containers. Photo by Don Willis.

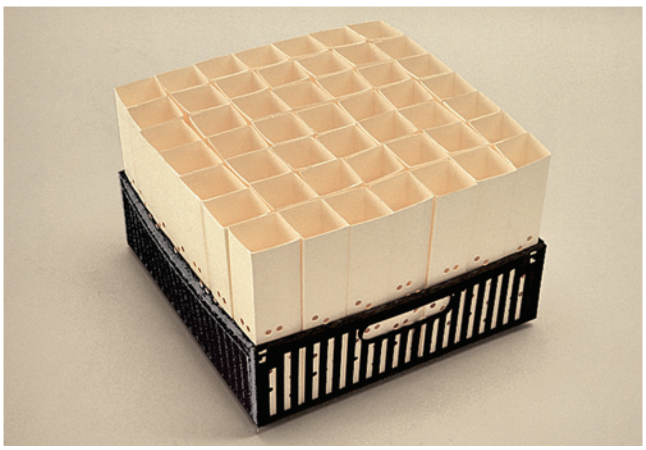

Figure 7.10—Zipset™ Plant Bands are inexpensive containers that can be shipped directly to the field. Photo courtesy of Stuewe and Sons, Inc.

container material broke down in the nursery before the plants were ready or they failed to decompose after outplanting. Still, new products are continually being introduced and are attractive to ecologically minded growers (Nambuthiri and others 2013; Chappell and Knox 2012).

Jiffy® Pellets and Pots

Jiffy® products consist of dry, compressed peat growing media inside a soft-walled, meshed bag and come in a variety of sizes (figure 7.9). When sown and irrigated, the pellet expands into a cylindrical plug surrounded by mesh that encourages air pruning all around the plug. Pellets are supported in hard plastic trays, so individual pellets can be consolidated to ensure full occupancy. Irrigation schedules must be adjusted (frequency increased) because of greater permeability of the container wall. Some root growth occurs between the pellets, so they must be vertically pruned before harvesting. Jiffy® Forestry Pellets are popular in forest nurseries in the Northeastern United States and Eastern Canada, where they are outplanted directly into the field. Smaller Jiffy® pellets are used for starting plants that are then transplanted into larger Jiffy® sizes or other containers. This system works well for species that germinate very slowly or over a long period of time.

Figure 7.11—Recyclable containers like these constructed of paper fiber are ecologically friendly but do not hold up well in wet, humid climates such as greenhouses. Photo by Tara Luna.

Zipset™ Plant Bands

Zipset™ Plant Bands are square, one-use containers composed of bleached cardboard containers that are assembled in a hard plastic tray (figure 7.10). Zipset™ Plant Bands maintain their integrity in the nursery but biodegrade after 9 to 18 months. Some tropical nurseries prefer Zipset™ Plant Bands because they protect the root plug during storage and shipping.

Other Natural Fiber Containers

Containers made of fiber, such as coir or compressed paper, come in a variety of sizes (figure 7.11) and are popular with gardeners for vegetable seedlings. The roots can develop without the potential deformity problems of solid-walled containers, and natural fiber pots can be transplanted or outplanted with minimal root disturbance or transplant shock. When they are outplanted, roots penetrate the container as it breaks down. These containers have a few problems, however, when used in tropical nurseries. They may break down too quickly in warm, humid climates to be suitable for growing native plants. They tend to become coated with algae over time, which makes them slippery to handle and nearly impossible to store, so they present challenges for shipping and handling. If a nursery is growing some fast-growing species that will not need to be transported very far before outplanting, natural fiber containers may be a suitable option. Natural fiber pots need to be tested before use to ensure they will not break down or become coated with algae too quickly for the growing cycle of the species propagated in them.

Figure 7.12*—The RootMaker®, which was the first to feature side-slit air pruning, is available as a single, free-standing container or in aggregate blocks. Photo by Tara Luna.*

Single, Free-Standing Containers

Several types of single-cell containers are being used to grow native plants for specific conditions.

RootMaker® Containers

These unique containers have staggered walls and a staggered bottom that prevent root circling and direct roots toward the holes in the walls and the bottom of the container. The containers were among the first to use side "air slits" to air prune plant roots (figure 7.12) and are available in many sizes of single containers that are either square or round. Smaller volume RootMaker® cavities are joined together in blocks.

Polybags and Polytubes

Bags made of black polyethylene (poly) plastic sheeting are the most commonly used nursery containers in the world because they are inexpensive and easy to ship and store (figure 7.13A). It is unfortunate but polybags generally produce seedlings with poorly formed root systems that spiral around the sides and the bottoms of the smooth-walled con-

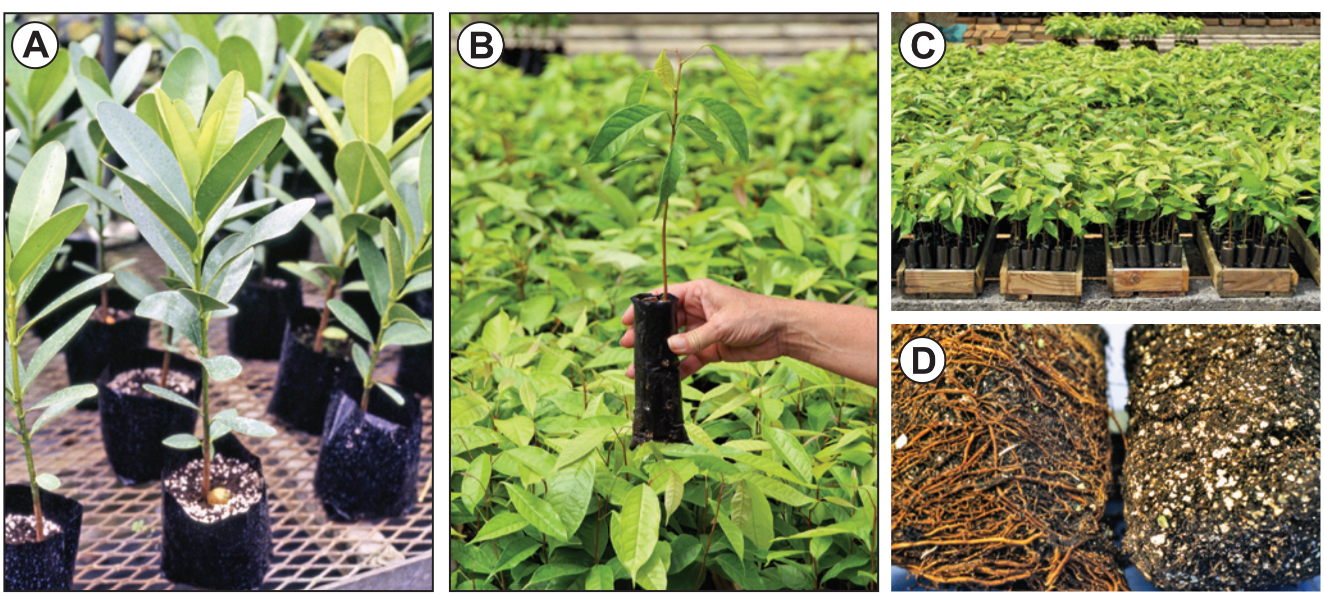

Figure 7.13*—Polybags are inexpensive containers (A) but can result in problems with seedling quality. Root spiraling is often serious, but polytubes in trays (B and C) and with copper-coating (D, on the right) can solve that problem. Photos A, B, and C by Tara Luna, and photo D by R. Kasten Dumroese.*

tainers. This problem worsens when seedlings are held over and not outplanted or transplanted at the proper time.

In cases in which converting to hard plastic containers would be operationally or financially impractical, ways exist to improve container production using polybags. Some of these cultural modifications include (Landis 1995)—

- Managing container seedlings as a perishable commodity with a limited "shelf life." This concept is particularly critical in tropical nurseries where seedlings grow year round. If seedlings cannot be outplanted when their roots fill the container, then they must be transplanted into a larger container. Holding over polybag seedlings is not an option.
- Using polytube containers (a polybag open at both ends, sometimes called a polysleeve) instead of polybags (figure 7.13B). These containers can usually be obtained from the same supplier as polybags or cut from a continuous roll with no bottom (Jaenicke 1999). Poly tubes eliminate much of the root spiraling. Poly tubes will hold growing media if they are properly filled and placed on elevated screen-bottomed trays to promote air pruning of roots (figure 7.13C).
- Using copper-coated polytubes or polybags. Plants grown in copper polybags produce a much finer, fibrous root system that is well distributed throughout the containers (figure 7.13D), but availability can be a problem.
- Switching from soil-based to "artificial" or organic-based growing media (composts, bark, or other materials instead of soil). See Chapter 6, Growing Media, for more information.
- Carefully transplanting germinants or direct-seeding into the polybag or polytube containers to avoid root deformations from improper transplanting of newly emerged seedlings.

Treepots™

These large-volume containers are constructed of flexible hard plastic and are good for growing trees and woody shrubs. Many sizes are available that are either square or round (figure 7.14A); square shapes increase space and irrigation efficiency in the growing area. Treepots™ feature vertical ribs on the inside wall to prevent root spiraling, are reusable, and store easily because they can be nested when empty. The depth of their root plug helps plants access soil water on dry sites and, for riparian restoration, provides stability against water erosion. Because of their large height-to-diameter ratios, Treepots™ require a support rack for growing and shipping (figure 7.14B), which can be made with fencing or other materials.

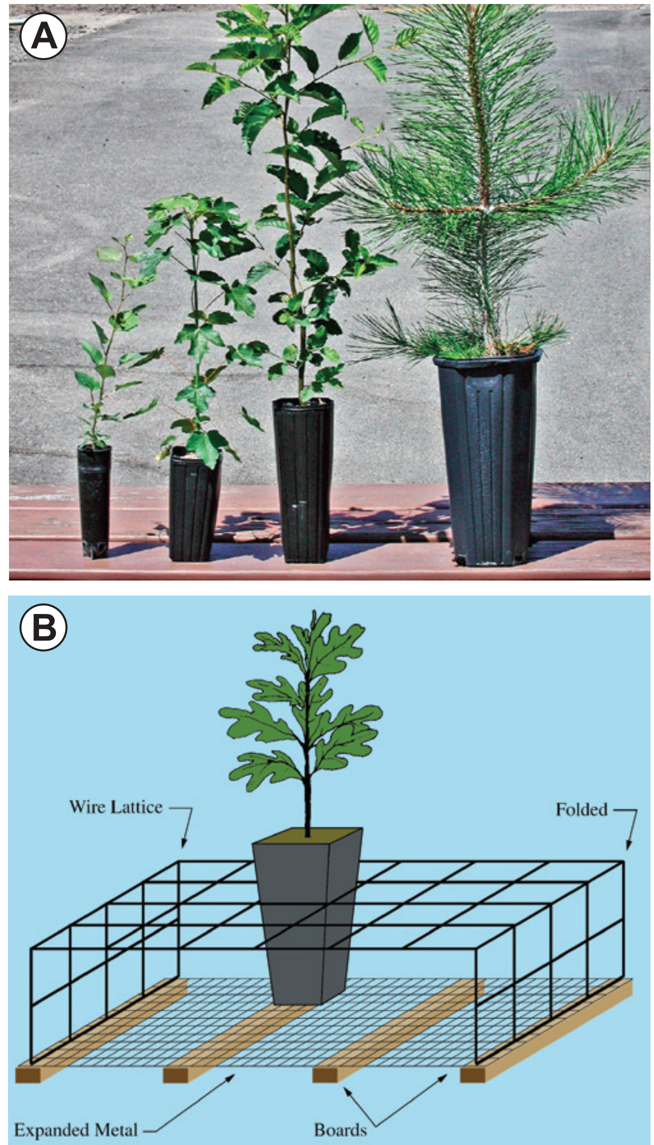

Figure 7.14*—Treepots™ are popular native plant containers because of their deep root systems (A), but they need to be held in a rack system (B). Photo A by Thomas D. Landis, and illustration B from Dumroese and others (2008).*

Round Pots

Round black plastic pots are available in many sizes from numerous manufacturers; one encouraging feature is that some brands are recyclable (figure 7.15A). Round pots are used in some tropical nurseries, especially for landscaping applications (figure 7.15B). Round pots are very durable and so can be reused for many years; because they can be nested when empty, they use little storage space. Most designs have a ridged lip that makes the pots easier to move and handle when they are wet. Root deformation has been a serious problem with these containers, although some are now available with internal ribs or copper coating to prevent root spiraling.

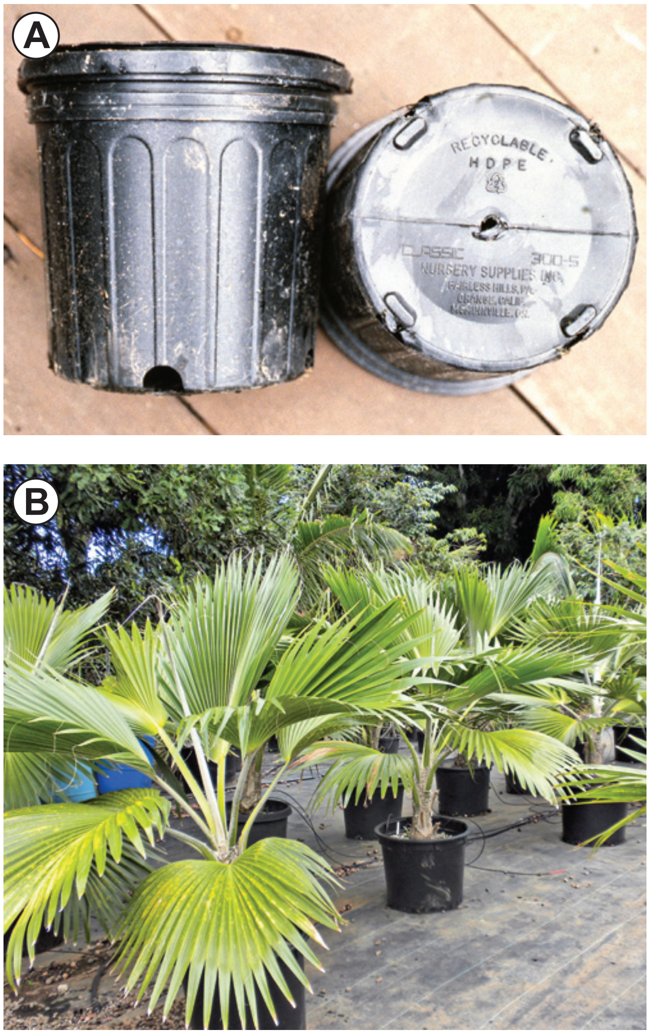

Figure 7.15—Some standard round plastic containers or "cans" are now recyclable (A), and are sometimes used to grow native plants for ornamental landscaping (B). Photo A by Thomas D. Landis, and photo B by Diane L. Haase.

Figure 7.16—Ray Leach Cone-tainer™ cells are one of the most popular container types for growing native plants (A) because they can be consolidated and spaced in the racks (B). Photos by Diane L. Haase.

Exchangeable Cells Held in a Tray or Rack

The major advantage of growing plants in individual cell containers supported in a hard plastic rack or tray is that the individual cells are interchangeable allowing for consolidation and spacing as described earlier. Racks are designed to create enough air space underneath to promote good air pruning. Plastic cells can be reused for several growing seasons.

Ray Leach Cone-tainer™ Cells

One of the oldest container designs on the market, the Ray Leach Cone-tainer™ cells are still popular with native plant growers. In this system, individual soft, flexible plastic cells are supported in a durable hard plastic tray (figure 7.16). Trays are partially vented to encourage air circulation between cells and have a life expectancy of 8 to 10 years. Cells come in three types of plastic: recycled, low density, and low density with UV stabilizers. All have anti-spiral ribs and a center bottom drainage hole with three or four side-drain holes on the tapered end.

Deepots™

These single cells are constructed of thick plastic and held in hard plastic racks (figure 7.17). Available in several sizes, they have internal vertical ribs for root control and supports on the bottom of each container provide stability. Racks hold the containers together but do not create an air space underneath, so Deepots™ must be grown on wire mesh or well-drained gravel to facilitate air pruning of the roots. Due to their large volume and depth, Deepots™ are popular with native plant nurseries growing woody shrubs and trees.

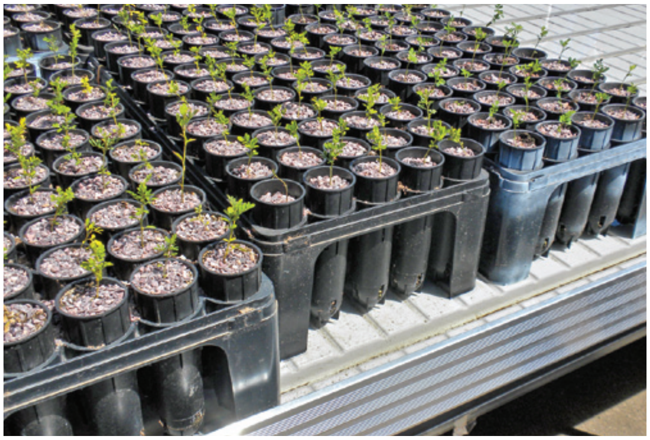

Figure 7.17—*Deepots™ come in large sizes and are popular for growing native shrubs and trees. Photo by Diane L. Haase.*

Book or Sleeve Containers: Spencer-Lemaire Rootrainers™

These unique "book" containers are composed of flexible plastic cells that are hinged at the bottom, allowing the growing media and root system to be examined during the entire growing season when the books are open (figure 7.18A). The books are held together in plastic or wire trays or "baskets" to form blocks of cells (figure 7.18B). As the name implies, Rootrainers™ have an internal rib system to guide plant roots to the drainage hole and to prevent spiraling. One real advantage of using the books is that they nest easily and can be shipped inexpensively; the nesting feature also makes for efficient storage. The plastic is less durable than other container types, but the books can be reused if handled properly.

Block Containers Made Up of Many Cavities or Cells

Styroblock™ and Copperblock™

Styroblock™ containers are the most popular type of container used in forest nurseries in the Western United States and are available in a wide range of cavity sizes and densities (figure 7.19), although outside block dimensions are standard to conform to equipment handling. This container has also been used for growing native grasses, woody shrubs, and trees. The insulation value of Styrofoam™ protects tender roots from temperature extremes and the white color reflects sunlight,

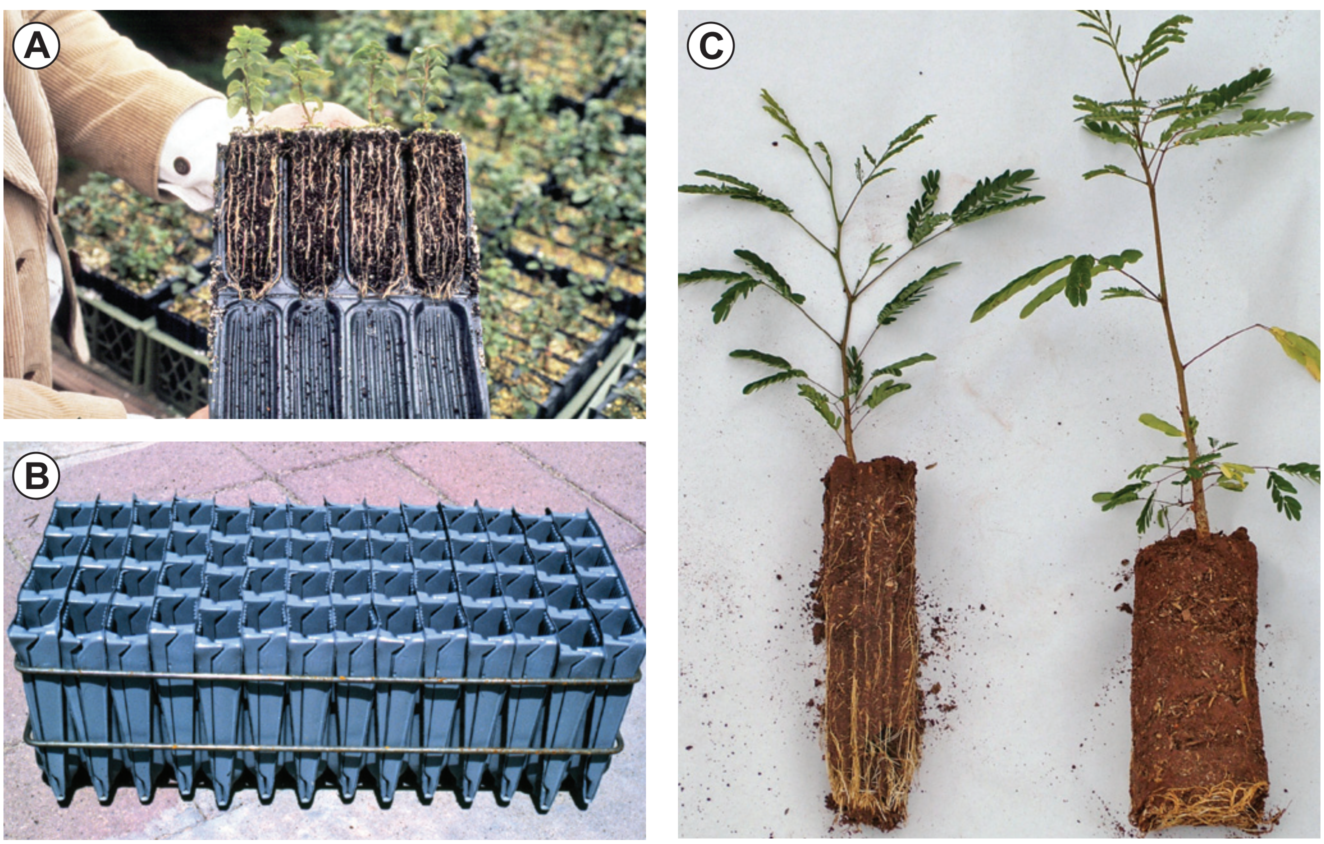

Figure 7.18—*Spencer-Lemaire Rootrainers™ are designed to allow easy inspection of growing media and the root plug (A). The hinged soft plastic sheets are assembled and placed into hard plastic trays or wire "baskets" to form blocks (B). In addition, these containers encourage good root formation along the length of the plug (left) compared with spiraled roots formed in the bottom of a polybag (right) (C). Photos A and B by Thomas D. Landis, and photo C by J.B. Friday.*

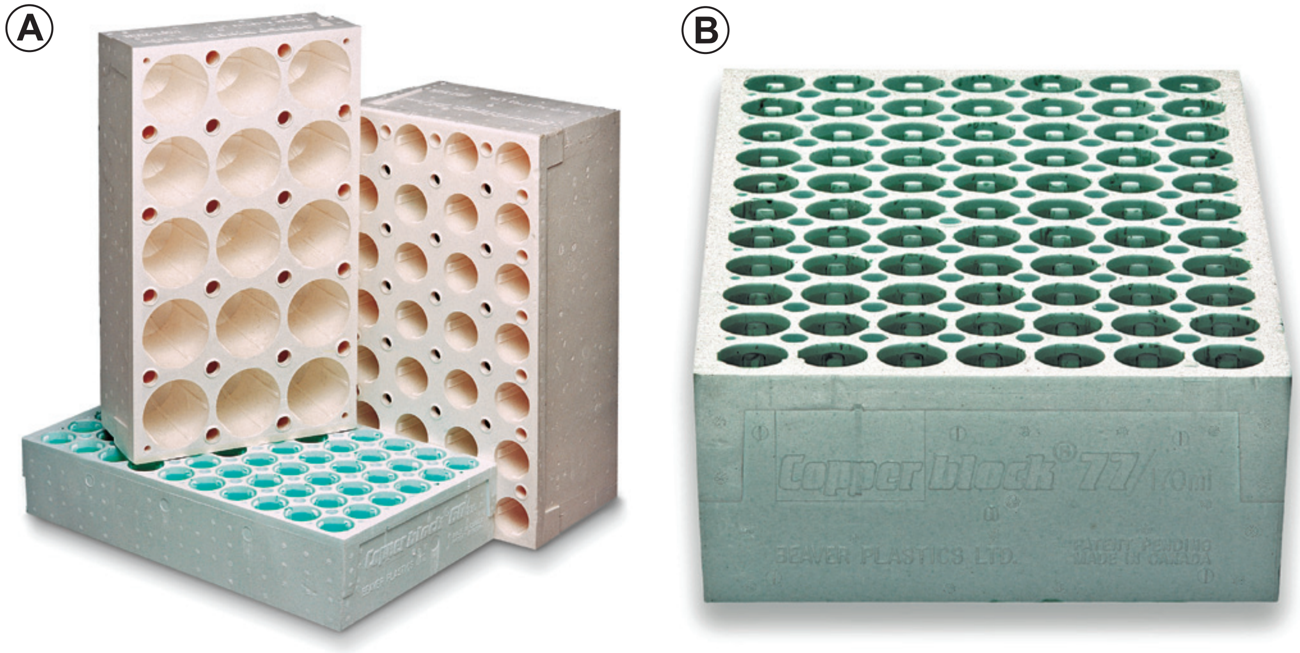

Figure 7.19—A wide assortment of Styroblock™ containers is available (A). The cavity walls of Copperblock™ containers are coated with copper, which causes chemical root pruning of species with aggressive roots systems (B). Styroblock™ and Copperblock™ containers have been used to grow a variety of native plants. Photo A courtesy of Stuewe and Sons, Inc., and photo B by Thomas D. Landis.

keeping the growing medium cool. Styroblock™ containers are relatively lightweight yet durable, tolerate handling, and can be reused for 3 to 5 years or more. One major drawback is that plants cannot be separated and consolidated so empty cavities and cull seedlings reduce space use efficiency. Species with aggressive roots may penetrate the inside walls of the cavities (especially in older containers reused for several crops), making the plugs difficult to remove. The Copperblock™ container is identical to the Styroblock™ except that it is one of the few commercially available containers with copper-lined cavity walls to promote root pruning.

Hardwall Plastic Blocks

Hardwall plastic blocks are available in a variety of cavity sizes and shapes and outside block dimensions (table 7.2). Extremely durable, these containers have a life expectancy of more than 10 years. The thick plastic is impervious to root growth.

Ropak® Multi-Pots are white in color, available in square and round cavity shapes, and have been used to grow a wide variety of species (figure. 7.20A). Because they are so durable, they are popular in mechanized nurseries and have been used to grow herbaceous and woody species. Cavity walls have vertical ribs to prevent root spiraling. IPL® Rigi-Pots™ are usually black, but other colors can be obtained in large orders. They are available in a variety of block dimensions and cavity sizes and shapes including sideslit models to encourage air pruning of roots (figure 7.20B). The Hiko™ Tray System features a variety of block and cavity sizes and shapes (table 7.2). All cavities have vertical root training ribs and sideslits (figure 7.20C). "The Groove Tube" Growing System™ features grooves in the side walls and large drainage holes to promote root development (figure 7.20D).

Miniplug Trays

Miniplug containers are used to start young seedlings that are transplanted into larger containers after establishment (figure 7.21). They are particularly useful for species with very small seeds that make precise seeding difficult. Multiple germinants can be thinned and plugs transplanted to larger containers. In these situations, the use of miniplug trays is much more space and labor efficient than direct seeding into larger cells. They require constant attention, however, because they dry out quickly. If miniplug trays are used, they may need to be irrigated several times a day or watered with automatic mist or subirrigation to keep them from drying out.

Seeds may also be started in trays, as discussed in Chapter 9, Seed Germination and Sowing Options.

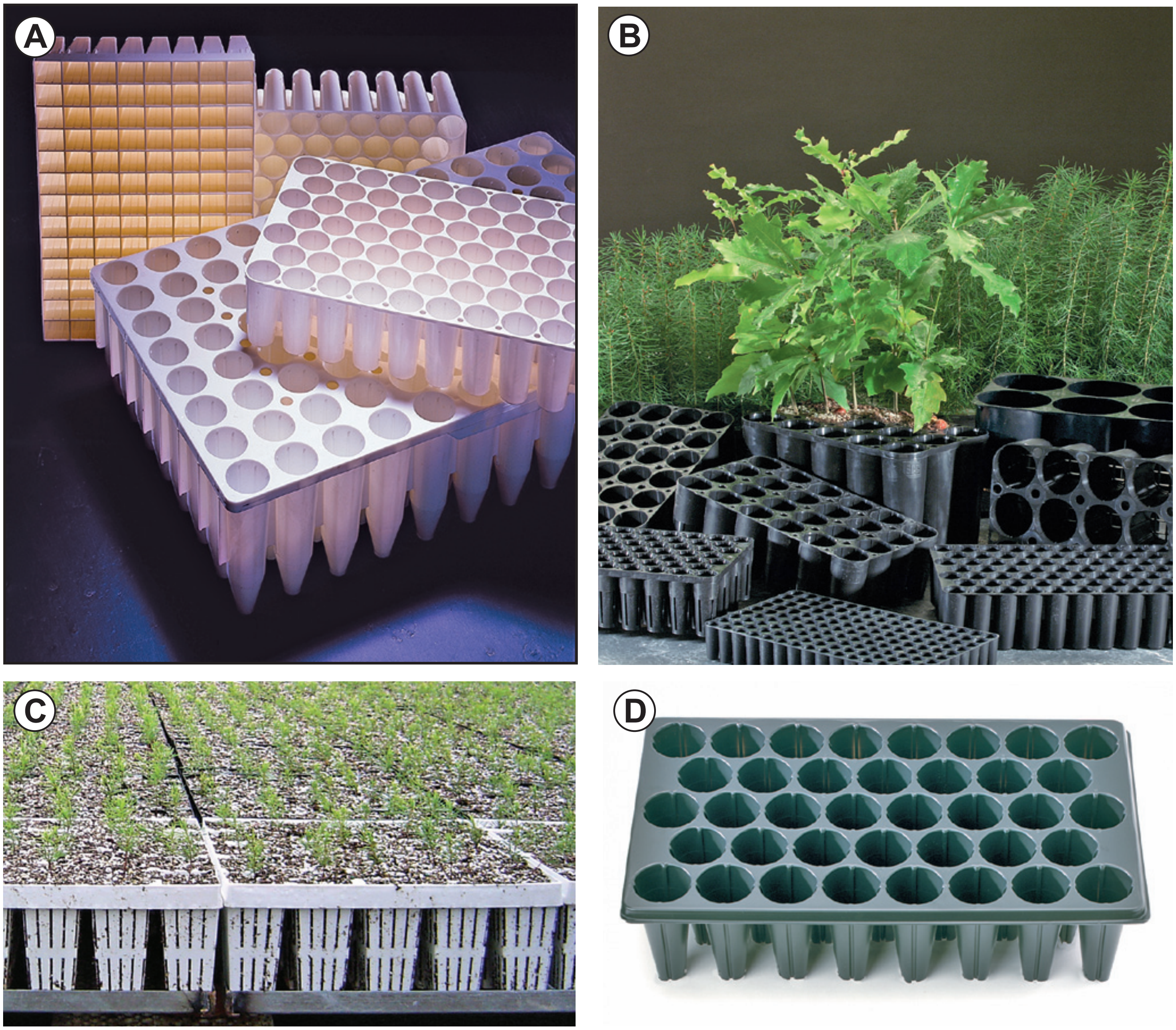

Figure 7.20—Hardwall plastic blocks are extremely durable containers made by several manufacturers. Ropak® Multi-Pots (A), IPL® Rigi-Pots (B), the Hiko™ Tray System (C), and the "Groove Tube" Growing System™(D). Photos A, C, and D courtesy of Stuewe and Sons, Inc., and photo B by Thomas D. Landis.

Figure 7.21—Miniplug containers are used to grow small seedlings that are transplanted into larger containers. Photo by Tara Luna.

Cleaning Reusable Containers

Most nursery containers are reusable. Charging a deposit (for example 10 cents per cell, refundable if returned within 30 days of plant delivery) or otherwise encouraging clients to return containers saves money and resources. Reusable containers usually have some residual growing medium or pieces of roots that could contain pathogenic fungi. Seedling roots sometimes grow into the pores of containers with rough-textured walls, such as Styroblock™ containers, and remain after the seedling plug has been extracted (figure 7.22A). Liverworts, moss, and algae also grow on containers and are very difficult to remove from reusable containers. Used containers should be washed first to remove old growing media and other debris. If available, a pressure washer is excellent for this purpose. Otherwise, a regular hose, or a soak in a garbage can followed by a rinse with a hose, works too.

Next, the containers should be sterilized. Because many tropical nurseries choose not to use pesticides and chemical disinfectants, hot-water dips are the most safe, environmentally friendly, and effective way to kill fungi and other pests in used containers. Most pathogens and weed seeds are killed when containers are held at 158 to 176 °F (40 to 60 °C) for more than 3 minutes (figure 7.22B). A good rule of thumb is to use a soaking temperature of 165 to 185 °F (75 to 85 °C) for 30 to 90 seconds for Styrofoam™ containers; 15 to 30 seconds is probably sufficient for hard plastic containers (Dumroese and others 2002). Soaking Styrofoam™ at hotter temperatures can cause the material to distort. Commercial units are available, but many nurseries have built homemade container dipping systems that hold the containers under hot water in a dip tank.

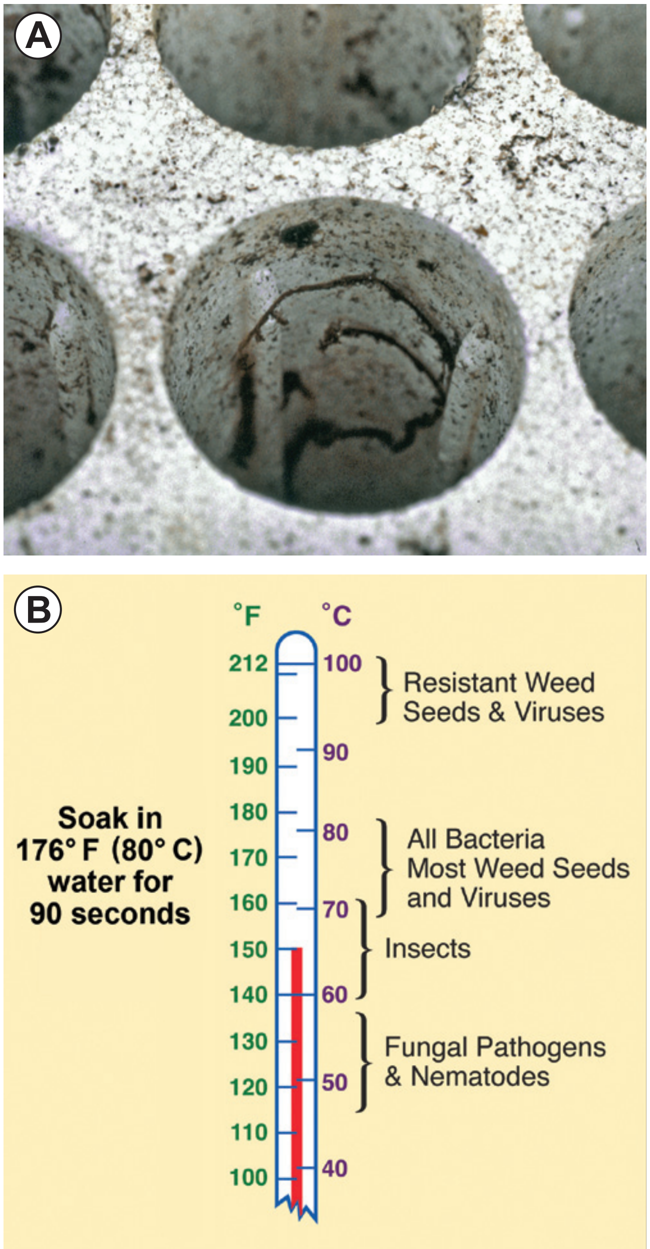

Figure 7.22—*Used containers should be washed and sterilized before reusing (A), because residual growing media and seedling roots can contain disease organisms. Submersion in water of 165 to 185 °F (75 to 85 °C) for 30 to 90 seconds has been shown to be adequate for all types of containers (B). Photo A by Thomas D. Landis, and illustration B adapted from Baker (1957) by Jim Marin.*

Other options for sterilizing containers and nursery tools include using household bleach or alcohol. These chemicals are phytotoxic to plants and should never be used on or near seedlings. For bleach, use regular household bleach (5.25-percent sodium hypochlorite concentration), diluted 1 part bleach to 9 parts water. Dip or soak the containers and tools in this bleach solution; then rinse them well before using. If the diluted bleach is stored in a covered container, such as a garbage can with a good lid, the solution may be used again, as long as it has not lost its strength. Wood, grain, or rubbing alcohol (70 to 100 percent) may also be used to sterilize containers and tools. Alcohol is used full strength. Dip or soak the containers and tools in the alcohol, but do not rinse them. Allow the containers and tools to dry in the air before using them.

References

Baker, K.F. 1957. The U.C. system for producing healthy container-grown plants through the use of clean soil, clean stock, and sanitation. University of California, Division of Agricultural Sciences, Manual 23. Berkeley, CA: University of California. 332 p.

Chappell, M.; Knox, G.W. 2012. Alternatives to petroleum-based containers for the nursery industry. Bulletin 1407. Athens, GA: University of Georgia, Cooperative Extension. 4 p. http://www.caes.uga.edu/applications/publications/files/pdf/B%201407_1.PDF. (March 2013).

Dumroese, R.K.; James, R.L.; Wenny, D.L. 2002. Hot water and copper coatings in reused containers decrease inoculum of *Fusarium* and *Cylindrocarpon* and increase Douglas-fir seedling growth. HortScience. 37(6): 943–947.

Dumroese, R.K.; Luna, T.; Landis, T.D. 2008. Nursery manual for native plants: volume 1, a guide for tribal nurseries. Agriculture Handbook 730. Washington, DC: U.S. Department of Agriculture, Forest Service. 302 p.

Jaenicke, H. 1999. Good tree nursery practices: practical guidelines for research nurseries. International Centre for Research in Agroforestry. Nairobi, Kenya: Majestic Printing Works. 93 p.

Landis, T.D. 1995. Improving polybag culture for sustainable nurseries. Forest Nursery Notes (July 1995): 6–7.

Nambuthiri, S.; Schnelle, R.; Fulcher, A.; Geneve, R.; Koeser, A.; Verlinden, S.; Conneway, R. 2013. Alternative containers for a sustainable greenhouse and nursery crop production. HortFact—6000. Lexington, KY: University of Kentucky Cooperative Extension Service, Horticulture Department. http://www.uky.edu/Ag/Horticulture/alternativecontainers.pdf. (March 2013).

Stuewe & Sons, Inc. 2013. Tree seedling nursery container catalog. http:/www.stuewe.com. (February 2013).

Additional Reading

Dumroese, R.K.; Wenny, D.L. 1997. An assessment of ponderosa pine seedlings grown in copper-coated polybags. Tree Planters' Notes. 48(3): 60–64.

Landis, T.D.; Tinus, R.W.; MacDonald, S.E.; Barnett, J.P. 1990. The container tree nursery manual: volume 2, containers and growing media. Agriculture Handbook 674. Washington, DC: U.S. Department of Agriculture, Forest Service. 88 p.